LEARNING CONCEPTUAL MODELING: STRUCTURING OVERVIEW, RESEARCH THEMES AND PATHS FOR FUTURE RESEARCH

Complete Research

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Abstract

Conceptual modeling marks an essential expertise for understanding and shaping the digital enterprise. Research on learning and, correspondingly, teaching conceptual modeling forms a diverse body of knowledge involving foci on various learning theories and approaches, learning outcomes and barriers. This review of literature on learning and teaching conceptual modeling identifies prevalent and emerging research themes, and presents a structuring overview of contributions to the field. Based on a systematic and purposeful sampling of publications combining different search strategies, we compile and analyze 121 contributions published between 1986 and 2017 to initiate further discussion on framing the learning and teaching of conceptual modeling in the light of learning paradigms. Future research can draw upon the identified research themes and gaps to advance our knowledge on learning conceptual modeling.

Keywords: Conceptual Modeling, Learning, Learning Paradigm, Learning Theory, Instructional Design, Literature Review.

1 Introduction

Conceptual modeling is an essential activity during information systems development and organizational analysis leading to purposeful reconstructions of statements about a domain of discourse using a modeling language, e.g., for data or process modeling (Frank, 1999; Wand and Weber, 2002; Weber, 2003). Conceptual modeling constitutes a learning task faced by most students of Information Systems (IS) and related fields such as Business Informatics and Software Engineering. It is mandated, e.g., by the joint standard curricula for Information Systems of the Association for Computing Machinery (ACM) and the Association for Information Systems (AIS) (Association for Computing Machinery, 2018). Viewed as a learning task, conceptual modeling involves an intricate array of cognitive processes and performed actions including abstracting, conceptualizing, associating, contextualizing, visualizing, interpreting & sense-making, judging & evaluating, and, in group settings, communicating, discussing and agreeing (Ternes et al., 2019). Learning conceptual modeling is, hence, construed as a complex task based on codified as well as tacit knowledge (Polanyi and Sen, 2009) with learning processes involving knowledge acquisition through experience (e.g., Venable, 1996). Learning conceptual modeling involves mastering theoretical foundations, modeling languages and methods, applying them to practical problems, and, along the way, critically thinking and reflecting upon an application domain and its technical language. It is, amongst others, for these reasons, that conceptual modeling is often perceived as particular challenging by learners. Specific challenges and learning difficulties have been identified, for example, regarding conceptualizing and labeling as well as related to reasoning and criticizing (Eid, 2012; Ryan et al., 2000; Sedrakyan et al., 2014b). Furthermore, teaching conceptual modeling is discussed as a correspondingly challenging task faced by didactic challenges (e.g., Bogdanova and Snoeck, 2017) as, for example, regarding the evaluation of conceptual models created by learners (Moisan and Rigault, 2010) and learner support via software tools (Sedrakyan and Snoeck, 2017).

Learning research is commonly acknowledged as an essential foundation for instructional design and for reasoned decision making in specific teaching and learning situations (e.g., Smith and Ragan, 2005, pp. 18f). For investigating the learning and teaching of conceptual modeling, learning paradigms constitute a theoretical lens which enables us to build on the vast body of knowledge on learning—informing the framing of the learning process (Hergenhahn, 1976). In the multifaceted literature on learning research, different learning paradigms are discussed including three main schools of thought—which interrelate and partly overlap (Harasim, 2012): The behaviorist (e.g., Watson, 1930), the cognitivist (e.g., Bruner, 1961) and the constructivist (e.g., Piaget, 1955; Vygotskij, 1962) paradigm. These learning paradigms link to learning approaches and teaching methods employed in teaching and learning conceptual modeling. For example, Schulte and Niere (2002) report on teaching object-oriented modeling based on the learning approach of active learning (e.g., Jonassen, 2002) which is essentially grounded in the constructivist learning paradigm. Another example is the work by Ryan et al. (2000) discussing learning of data modeling based on social cognitive theory (Bandura, 1986) following the cognitivist tradition on learning.

Due to its relevance for IS education and practice (Fettke, 2009; Frank, 1999), research on learning conceptual modeling has for long received interest with recent contributions, e.g., focusing on business process modeling (Claes et al., 2015), model-driven development (Pastor et al., 2016) and automated personalized feedback to learners (Serral et al., 2016; Serral and Snoeck, 2016). However, a comprehensive overview of research covering prevalent and emerging themes in the scientific discourse is, to our knowledge, missing at present. The few related overview articles have different foci, e.g., curricula on teaching modeling in software development (Börstler et al., 2012), tools used in modeling education (Agner and Lethbridge, 2017) or technology-mediated learning in the IS field (Alavi and Leidner, 2001). In contrast, the present literature study reviews prior work on learning and teaching conceptual modeling published until January 2018 aiming at an insightful synthesis of the literature (Leidner, 2018). Specifically, the research at hand pursues a twofold objective:

(1) The main objective of this study is to provide a structuring overview of the body of literature on learning and teaching conceptual modeling guided by learning paradigms.

(2) The secondary research objective is to identify prevalent and emerging phenomena in research on learning and teaching conceptual modeling and to detect research gaps in the literature.

Consequently, this study is aimed at informing future research on learning and teaching conceptual modeling, e.g., design research on tool support, by initiating further discussion on framing the learning of conceptual modeling in the light of learning paradigms and by suggesting potential paths for future research in the field (following, e.g., Rowe, 2014). To achieve a comprehensive account of research on learning and teaching conceptual modeling, the literature retrieval is based on a systematic and purposeful sampling of publications combining different search strategies (vom Brocke et al., 2009; Webster and Watson, 2002). The present study builds on a broad definition of conceptual modeling including static, functional and dynamic abstractions (Brodie et al., 1984; Embley and Thalheim, 2011) and its learning to account for the multidisciplinarity of the research field and to include contributions from various disciplines as, e.g., Information Systems, Software Engineering, Cognitive Science, Learning and Education Science.

The next section (Sect. 2) introduces theoretical background and the three main learning paradigms. Section 3 reports on the design of the literature review, Sect. 4 summarizes findings of the literature analysis. A discussion of the findings and of future research directions is given in Sect. 5. Section 6 concludes with a reflective commentary.

2 Theoretical Background

In order to prepare our analysis, this section provides an introduction to the main concepts *learning paradigm*, *learning approach* and *teaching method* and outlines the three main schools of thought.

Different conceptualizations of learning and interpretations of the learning process, i.e., how learning occurs, jointly referred to as *learning paradigm* (or theory of learning) have been suggested in literature and, have been subject to controversial discussion in educational psychology, Cognitive Science, Instructional Design and in the learning sciences in general. In a prescriptive manner—and thus contrary to learning paradigms—*learning approaches* (also referred to as forms of learning or educational approaches) suggest how the process of learning is performed and, typically, can be associated with one learning paradigm—though a distinct classification may not succeed in all cases. Learning approaches typically comprise different *teaching methods* (or instructional methods) which provide guidance for concrete course design and instruction. Other learning approaches in the context of learning and teaching conceptual modeling are based on different theories as, for example, cognitive theories including cognitive load theory (e.g., Chandler and Sweller, 1991) and social cognitive theory (Bandura, 1986). In the following, the three main schools of thought are briefly outlined (Ertmer and Newby, 2013; Harasim, 2012). It has to be noted, however, that this classification of main schools of thought on learning is discussed as controversial (e.g., Siemens, 2005). Furthermore, it is common in teaching applications that conceptions and principles are combined following multiple paradigms—and adapted to the particular learning/teaching situation (e.g., Ertmer and Newby, 2013, pp. 60f, Sedrakyan and Snoeck, 2017, p. 71).

Behaviorism, as term dating back to Watson (1930), is widely seen as the dominant approach in the American and British Learning Psychology prior to the 1980s (e.g, Illeris, 2012, p. 19). From a behaviorist learning perspective, consciousness and internal mental states cannot be studied in a reliable manner yet only observable behavior which varies with experience (e.g., Hergenhahn, 1976, p. 49). Thus, behaviorism suggests to study observable human behavior affected by external stimuli. Following the behaviorist paradigm, learning can be seen as a stimulus-response process leading to a change in behavior of the learner. To increase the probability that an antecedent behavior will occur again or to change behavior, both positive and negative reinforcement are employed. The basic assumption of a behaviorist perspective on learning is that a learner is essentially passively responding to environmental stimuli. For example, classical conditioning applied by Pavlov (e.g., Pavlov, 1968) and operant conditioning going back to Skinner (e.g., Skinner, 1976) are examples of a behaviorist learning mindset. However, although behaviorism has a long tradition, it does not have the same relevance for research on learning and teaching nowadays as cognitivism and constructivism (e.g., Ertmer and Newby, 2013, Murtonen et al., 2017, p. 115): With the cognitive turn, starting in the 1950s and gaining momentum in the 1970s, behaviorist perspectives have been strongly criticized for not being appropriate to explain complex conceptual learning. Hence, for learning conceptual modeling as a complex, conceptual learning task greater importance is ascribed to the cognitivist and constructivist learning paradigms.

Cognitivism essentially argues that—contrary to behaviorism as learning paradigm—the black box of the mind should be opened and, thus, learning research should focus on inner mental activities and cognitive processes such as thinking, memorizing, problem solving and conceptualizing (Ertmer and Newby, 2013, pp. 50–54, Harasim, 2012, pp. 11f): From the cognitivist learning perspective, learning can be characterized as changes in states of knowledge—emphasizing knowing rather than responding (Howard, 1983, pp. 5–7). The learner is viewed as active participant in the learning process who actively acquires knowledge—metaphorically viewed as a computer which internally processes incoming information. In a nutshell, cognitivism focuses on the knowledge of learners and how it is acquired (Jonassen, 1991, p. 6). As examples, the social cognitive theory (Bandura, 1986) and the cognitive theory of multimedia learning (Mayer, 2009) are described as examples of a cognitivist learning mindset.

Constructivism, questioning the essentially objectivistic assumptions of behaviorism and cognitivism, is considered to be the dominant learning paradigm at present (Ertmer and Newby, 2013, p. 67). The constructivist perspective is typically associated with the ideas of Piaget (e.g., Piaget, 1955) and Bruner (e.g.,

Bruner, 1961). Following constructivism, learning is seen as the construction of meaning by interpreting experiences (Jonassen, 1991, p. 10). The learner is viewed as independently constructing her own subjective representations and understandings of reality through critical reflection—meaning is created and not acquired (e.g., Ertmer and Newby, 2013, p. 55, Jonassen, 1991, p. 10). The approach of active learning (see Jonassen, 2002, p. 2) and the teaching method of problem-based learning, commonly labeled as active learning (e.g., Prince, 2004, p. 228), are characterized as primarily following the constructivist learning paradigm. In constructivism as learning paradigm, a socio-cultural perspective on learning, i.a., going back to Vygotskij (e.g., Vygotskij, 1962), emphasizes that learning occurs in complex social and cultural environments and cannot be studied as process solely taking place within the learner's mind (Sawyer, 2006, p. 9).
This broad classification into three main schools of thought allows us to analyze and categorize prior work on learning and teaching conceptual modeling regarding theoretical foundations—informing further discussion on framing the learning and teaching of conceptual modeling in the light of learning paradigms.

3 Research Design of the Literature Review

Literature retrieval. The present literature study constitutes a standalone, systematic literature review aimed at synthesizing prior work on learning and teaching conceptual modeling based on an intentionally comprehensive sampling of prior work (e.g., vom Brocke et al., 2015, p. 207). To be as inclusive as possible, the literature retrieval follows a twofold process: In line with Webster and Watson (2002), database keyword searches are complemented with backward and forward searches to include not only publications in journals and conference proceedings indexed in electronic databases but to also include contributions in other publication types such as monographs, anthologies and proceedings not indexed in databases. Database searches as well as forward and backward searches include publications up to January 2018. The searches are limited to results published in English. In Cooper's (1988) typology of literature reviews, the present work qualifies as "exhaustive with selective citation".

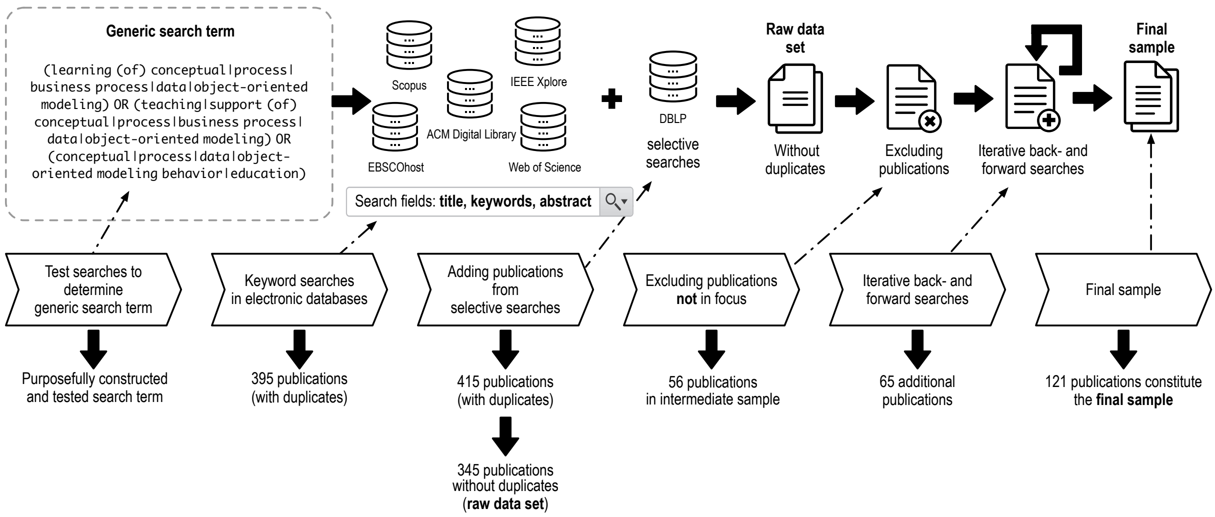

Figure 1. Literature retrieval.

The literature retrieval commenced with searches in electronic databases using a purposefully constructed and tested search term derived from the research objectives of the study (vom Brocke et al., 2009, p. 2214). As the focus of the literature review is on *learning conceptual modeling*, the phrase `learning (of) conceptual|process|business process|data|object-oriented modeling` constitutes the first part of the search term. To include publications reporting on *teaching conceptual modeling* (e.g., teaching cases) or *supporting learners* (e.g., novices in conceptual modeling), the phrase `teaching|support` `(of) conceptual|process|business process|data|object-oriented modeling` is included as second part of the search term. Publications relevant to the focus of this review also use the terms *modeling behavior* (e.g., Sedrakyan and Snoeck, 2017) and *modeling education* (e.g., Brandsteidl et al., 2011). However, test searches solely using the terms *modeling behavior* or *modeling education* produced far too many results irrelevant for the purpose of this study. Hence, the more specific phrase `conceptual|process|data|object-oriented modeling behavior|education` has been used as third part of the search term. Thus, the inclusive disjunction of these three parts was applied as generic search term for database searches (complemented with British English spelling, see Fig. 1). Keyword searches in the fields *title*, *keywords* and *abstract* with the generic search term tailored to the search query syntax of the respective database were performed in the following electronic databases: *ACM Digital Library* (The ACM Guide to Computing Literature, 134 results), *IEEE Xplore digital library* (28 results), *EBSCOhost* (Business Source Ultimate & Education Source, 27 results) and *Scopus* (203 results). In the *Web of Science Core Collection*, the generic search term was tailored for searches in the fields *title* and *topic* (3 results). Unfortunately, the *Digital Bibliography & Library Project* (DBLP) does not provide phrase searches at the moment and searches using the conjunction of the words constituting the generic search term produced too many results not relevant for the scope of the present review. However, test searches in the DBLP resulted in publications we assumed relevant to the focus of the present study—leading to the decision to perform selective searches with the terms used in the generic search term (20 results). Aligned with the aim of an exhaustive review of prior work, the selection of electronic databases comprises core databases on IS and computer science subjects (ACM Digital Library, IEEE Xplore digital library, DBLP) as well as cross-disciplinary databases (Scopus, Web of Science, EBSCOhost)—to cope with the multidisciplinary topic of the present review. Overall, the searches in electronic databases resulted in a raw data set of 345 publications without duplicates (415 with duplicates).

As a next step, publications not in our research focus were excluded. Fulfilling the following *inclusion criteria* was required for each publication to be included in the final sample of publications: (1) Original research contribution or teaching/experience report published in English and (2) focus on the learning and/or teaching of conceptual modeling or focus on supporting, facilitating or assisting the learning of conceptual modeling, e.g., applying specific teaching methods or tool support. All 345 publications in the raw data set were reviewed and discarded if they did not meet the inclusion criteria by considering titles, abstracts, and, in doubt, the full texts of the publications. Excluding results not qualifying as research contribution resulted in discarding, e.g., nine conference proceedings, two conference prefaces and one editorial. Moreover, two publications not published in English were excluded. Likewise, publications only marginally referring to learning and teaching conceptual modeling were excluded in line with the second criterion, for example, approaches with a focus on technology support for collaborative process modeling (Recker et al., 2013). Also results on modeling of learning processes were excluded (Naeve et al., 2008) as well as publications discussing replacing the ER Model by UML for teaching data modeling (Suleiman and Garfield, 2006). A consensus between the first two authors participating in this step was required to exclude a contribution. At this stage, the literature retrieval resulted in a sample of 56 publications.

To obtain additional relevant publications not covered so far by our search strategies as, e.g., monographs or articles published in anthologies, backward and forward searches were conducted (e.g., Webster and Watson, 2002, p. xvi). In an iterative process, the first two authors manually scrutinized the bibliographies of all publications in the intermediate sample and the results of forward searches performed with the search engine Google Scholar identifying contributions citing the publications included in the intermediate sample. The search was terminated when no new publications relevant for the present review were identified indicating a certain level of saturation (vom Brocke et al., 2015, pp. 211f). Viewing titles, abstracts and, in doubt, the full texts of publications assessing the fulfillment of the set inclusion criteria led to 65 additional results in this step. Including a publication required a consensus between the two participating authors. For example, publications focusing on user interface design rather than learning and teaching conceptual modeling were not included (e.g., Ruiz et al., 2015). Altogether, 121 publications constitute the final sample. A list of the publications in the final sample and in the raw data set is available online as supplementary material (Rosenthal et al., 2019).

Literature analysis and synthesis. To provide a structuring and organizing overview of the field of learning and teaching conceptual modeling, the first step of the analysis educed the publication profile in terms of the numbers of scientific publications over time and if the publications in the final sample focus on, e.g., (business) process modeling, data modeling, object-oriented modeling or address conceptual modeling in general. As a next step, we purposefully read the papers in the final sample to categorize and analyze the publications with regard to underlying learning paradigms, learning approaches and applied teaching methods. Thereby, categorizing a publication presupposed an explicit mentioning of the paradigm, approach or method. As a further step, we coded the publications in the final sample on addressed research themes by systematically assigning publications to concepts representing research themes (e.g., King and He, 2005), starting with open coding and allowing for revising and refining codes. This process of open coding was repeated until no new research themes were identified, i.e., a certain level of saturation had been achieved. This coding strategy led us to identify prevalent and emerging themes in the research field and to structure prior work along identified research themes.
Limitations. The research design is subject to a number of limitations: The literature retrieval—although based on a systematic purposeful sampling of publications—does not necessarily lead to a complete census of relevant literature (vom Brocke et al., 2009, p. 2207). Excluding publications not in the focus of the study and scrutinizing results of backward and forward searches entails the risk of misleading decisions on relevance for the scope of the review. The literature analysis regarding learning paradigms, approaches, theories and teaching methods relies on the explicit mentioning of the concepts in the analyzed publications. This is not an exclusive way to categorize the publications and it does not consider implicit assumptions in the reviewed work. However, this review is targeted at identifying and compiling explicit reflections on concepts from learning research (i.a., learning paradigms, learning approaches) in prior work on learning and teaching conceptual modeling. Thus, we deem the used analysis approach as appropriate. Moreover, the focus of the review is on underlying learning paradigms as well as on discovering prevalent and emerging themes in research on learning and teaching conceptual modeling. Other aspects are not reviewed in detail as, for example, the use of tools in modeling education—which constitutes a research topic recently addressed in a survey (Agner and Lethbridge, 2017).

4 Findings

The final sample includes 121 contributions published between 1986 and 2017. Viewing the final sample by year of publication indicates a growing research interest in learning and teaching conceptual modeling starting around the turn of the century with the bulk of publications (103) published after 2004 (see Fig. 2).

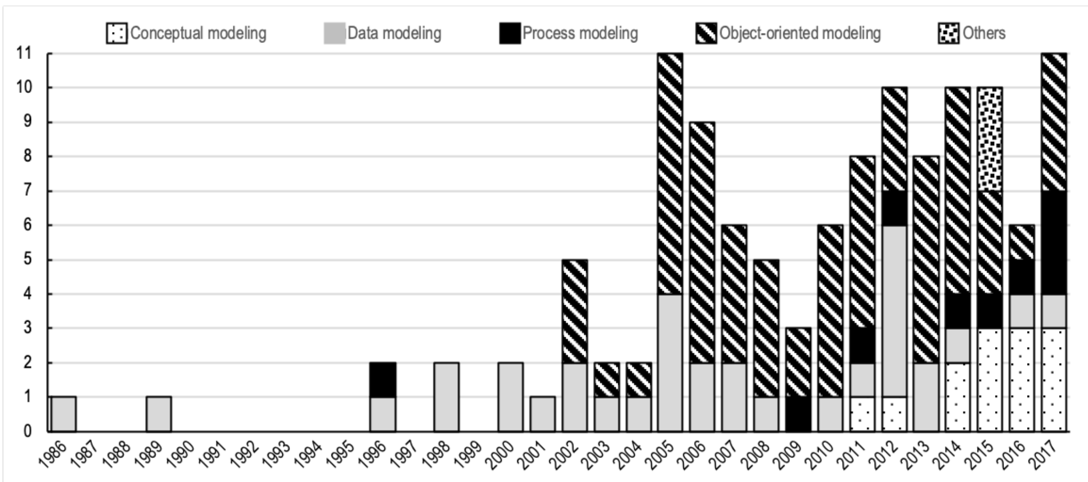

Figure 2. Numbers of publications and foci of publications in the final sample from 1986 to 2017.

Interestingly, about half of the 121 publications (62) address object-oriented modeling constituting the largest group of publications. About a quarter of the publications (33) focuses on data modeling, 13 publications address conceptual modeling in general, while 10 publications have a focus on (business) process modeling. In addition, two publications focus on enterprise modeling (Bider et al., 2015a,b) and one publication focuses on teaching goal modeling with i* (Paja et al., 2015) (subsumed under the identifier 'Others' in Fig. 2).

Learning Paradigm		**11**
Behaviorism	Sedrakyan and Snoeck (2017)	1
Cognitivism	Elva and Workman (2008)	1
Constructivism	Bork et al. (2015), Brinda (2006), Buchmann and Ghiran (2017), Connolly and Begg (2006), Eid (2012), Fong et al. (2011), Holmboe (2005b), Sedrakyan and Snoeck (2017), Snoeck et al. (2007), and Zhuoyi et al. (2012)	10
Learning approach		**24**
Active learning	Börstler (2010), Hansen and Ratzer (2002), Marsicano et al. (2016), Schulte and Niere (2002), and Silva et al. (2017)	5
Collaborative learning	Baghaei and Mitrovic (2005, 2006), Baghaei et al. (2007), Basheri et al. (2013), Börstler and Schulte (2005), de los Angeles Constantino-Gonzaléz and Suthers (2000), de los Angeles Constantino-Gonzaléz et al. (2003), Dittmar et al. (2017), Gordon and Hall (1998), Koutsopoulos and Bider (2017), and Ramollari et al. (2011)	11
Cooperative learning	Ryan et al. (2000)	1
Discovery learning	Brinda (2003, 2006)	2
Experiential learning	Bider et al. (2015c) and Oppl and Hoppenbrouwers (2017)	2
Self-regulated learning	Sedrakyan and Snoeck (2013, 2015) and Sedrakyan et al. (2014b)	3
Learning theory		**10**
Cognitive apprenticeship	Connolly and Begg (2006) and Schulte and Niere (2002)	2
Cognitive dissonance theory	de los Angeles Constantino-Gonzaléz et al. (2003)	1
Cognitive load theory	Claes et al. (2017), Eid (2012), and Sin (2009)	3
Multimedia learning theory	Recker et al. (2014)	1
Social cognitive theory	Ryan et al. (2000)	1
Socio-cognitive conflict theory	de los Angeles Constantino-Gonzaléz and Suthers (2000) and de los Angeles Constantino-Gonzaléz et al. (2003)	2
Socio-cultural theory	Holmboe (2005a)	1
Student learning theory	Recker et al. (2014)	1
Teaching method		**7**
Case-based learning	Bider et al. (2015a)	1
Example-based learning	Silva et al. (2017)	1
(Digital) Game-based learning	Boughzala et al. (2017) and Cosentino et al. (2017)	2
Problem-based learning	Akayama et al. (2012) and Silva et al. (2017)	2
Project-based learning	Connolly and Begg (2006) and Marsicano et al. (2016)	2

Table 1. Learning paradigms, learning approaches, learning theories and teaching methods used in the review sample (multiple assignments allowed).

4.1 Learning paradigms, learning approaches and teaching methods

Reviewing the publications in the sample shows that only 11 publications explicitly reflect on a paradigm (see Tab. 1): Less than a tenth of the sample (9 publications) explicitly refer to constructivism as learning paradigm (Bork et al., 2015; Brinda, 2006; Buchmann and Ghiran, 2017; Connolly and Begg, 2006; Eid, 2012; Fong et al., 2011; Holmboe, 2005b; Snoeck et al., 2007; Zhuoyi et al., 2012) while only one publication explicitly refers to the cognitive theory of learning (Elva and Workman, 2008)—which is surprising in the light of the relevance of cognitivism as well as constructivism for research on learning and teaching (e.g., Biggs, 1996; Ertmer and Newby, 2013). A solely behaviorist learning paradigm is not explicitly mentioned by any publication in the sample—which is in line with the criticism that behaviorism is not able to explain complex, conceptual learning tasks (e.g., Murtonen et al., 2017, p. 115). Sedrakyan and Snoeck (2017) refer to both a constructivist and a behaviorist perspective to provide feedback to learners of conceptual modeling.

About a quarter of the publications in the final sample (24 publications) explicitly refers to specific learning approaches. The most frequently mentioned learning approaches are collaborative learning (11 contributions), which can be associated with a socio-cultural perspective on learning, followed by active learning (5 contributions) and self-regulated learning (3 contributions), which both can be characterized as primarily constructivist. In addition, cooperative learning, discovery learning and experiential learning are used in isolated cases in the review sample. Moreover, 10 publications refer to learning approaches based on theories applied in the context of learning and teaching including 7 publications referring to theories which can be associated with a primarily cognitivist learning paradigm, i.e., cognitive load theory (Claes et al., 2017; Eid, 2012; Sin, 2009), multimedia learning theory (Recker et al., 2014), social cognitive theory (Ryan et al., 2000), cognitive dissonance theory (de los Angeles Constantino-Gonzaléz et al., 2003) and socio-cognitive conflict theory (de los Angeles Constantino-Gonzaléz and Suthers, 2000; de los Angeles Constantino-Gonzaléz et al., 2003). The student learning theory is applied in Recker et al. (2014) and the cognitive apprenticeship theory in Connolly and Begg (2006) as well as Schulte and Niere (2002) which can both be characterized as primarily constructivist (Biggs, 1999). Holmboe (2005a) explicitly reflects on a socio-cultural perspective on learning, constituting a marked exception. Specific teaching methods are referred to in only 7 publications including (digital) game-based learning, problem-based learning and project-based learning (2 publications each) as well as case-based learning (Bider et al., 2015a) and example-based learning (Silva et al., 2017). Note that the learning approaches and teaching methods interrelate and overlap, e.g., problem- and project-based learning are teaching methods following the learning approach of active learning (e.g., Prince, 2004, p. 228). As a whole, it is especially remarkable that a considerably high number of 79 publications in the sample do not explicitly refer to or reflect on a learning paradigm, learning approach, theories in the context of learning or a specific teaching method.

4.2 Prevalent and emerging research themes

Reviewing prior work on learning and teaching conceptual modeling leads us to identify four prevalent phenomena which emerged from reviewing the publications in the final sample: (i) learning tool support, (ii) feedback, (iii) learning analytics and (iv) gamification/serious games. An overview of the identified research themes and related publications in the review sample is shown in Tab. 2. This section explains the four research themes and provides examples of publications for each theme.

(i) Learning tool support: Tool support for learning and teaching conceptual modeling is the predominant research theme as about half of the publications in the final sample, precisely 63 publications, suggest tool support for learning and teaching conceptual modeling. As primary theme, *modeling tool support* is suggested in 49 contributions, i.e., developing, advancing or using a tool offering modeling functionalities which assists in learning or teaching conceptual modeling (not included are tools solely providing modeling functionalities that do not offer specific support for learning or teaching, i.e., regular modeling tools; for an overview of the use of tools in modeling education, see the results of a survey in Agner and Lethbridge, 2017). Modeling tool support is not restricted to specific abstractions but rather includes object-oriented modeling (e.g., Baghaei et al., 2007; Ramollari et al., 2011), data modeling (e.g., Schulte and Niere, 2002; Suraweera and Mitrovic, 2004), process modeling (e.g., Marsden and O'Connell, 1996) and conceptual modeling in general (e.g., Serral et al., 2016). Learning assistance and teaching support is implemented in different forms including automatic correction of models (e.g., Soler et al., 2010b), feedback (e.g., Serral et al., 2016) and tutoring (e.g., Baghaei et al., 2006). As specific modeling tool support, the use of model-driven development functionalities is proposed in 4 publications comprising support for the learning of conceptual modeling (Kayama et al., 2015; Pastor et al., 2016) and object-oriented modeling (Akayama et al., 2013; Akayama et al., 2012). Additionally, 5 publications suggest to support learning by use of "simulation" of conceptual models in the sense of generating prototype applications based on

(i) Learning tool support		**63**
Modeling tool support for		**49**
Object-oriented modeling	Akayama et al. (2013), Akayama et al. (2012), Alonso and Py (2009), Alonso et al. (2008), Auxepaules and Py (2010), Auxepaules et al. (2008), Baghaei and Mitrovic (2005, 2006), Baghaei et al. (2005, 2006, 2007), Brinda (2006), Dranidis (2007), Dranidis et al. (2015), Hansen and Ratzer (2002), Py et al. (2008, 2013), Ramollari and Dranidis (2007), Ramollari et al. (2011), Sedrakyan and Snoeck (2012, 2013, 2015, 2017), Sedrakyan et al. (2014b), Snoeck et al. (2007), Soler et al. (2010a,b), and Virvou and Tourtoglou (2006)	28
Data modeling	de los Angeles Constantino-Gonzaléz and Suthers (2000), de los Angeles Constantino-Gonzaléz et al. (2003), Eid (2012), Fong et al. (2011), Gordon and Hall (1998), Hall and Gordon (1998), Jukic et al. (2013), Keberle and Utkin (2012), Kung and Kung (2013), Kung and Tung (2010), Prados et al. (2006), Schulte and Niere (2002), and Suraweera and Mitrovic (2001, 2002, 2004)	15
Process modeling	Claes et al. (2015), Marsden and O'Connell (1996), and Oppl and Hoppenbrouwers (2017)	3
Conceptual modeling	Kayama et al. (2015), Pastor et al. (2016), and Serral et al. (2016)	3
Learning management systems/e-learning platforms for		**13**
Object-oriented modeling	Brandsteidl et al. (2013, 2011), Koivulahti-Ojala (2017), Koivulahti-Ojala and Käkölä (2012, 2014), Ramollari et al. (2011), Soler et al. (2010a,b), and Tsarmpou and Tambouris (2015)	9
Data modeling	Prados et al. (2006)	1
Process modeling	Neubauer (2012) and Shabalina et al. (2015)	2
Conceptual modeling	Daun et al. (2017)	1
Others	Al-Tahat (2014), Antony et al. (2005), Antony and Santhanam (2007), and Bider et al. (2015a,b)	**5**
(ii) Feedback		**32**
Process-oriented feedback for		**22**
Object-oriented modeling	Baghaei and Mitrovic (2006), Baghaei et al. (2005, 2006, 2007), Moreira and Ferreira (2016), Py et al. (2008, 2013), Sedrakyan and Snoeck (2012, 2013, 2015, 2017), Sedrakyan et al. (2014a), Sedrakyan et al. (2014b), and Snoeck et al. (2007)	14
Data modeling	de los Angeles Constantino-Gonzaléz and Suthers (2000), de los Angeles Constantino-Gonzaléz et al. (2003), Gordon and Hall (1998), Hall and Gordon (1998), and Suraweera and Mitrovic (2001, 2002, 2004)	7
Conceptual modeling	Serral et al. (2016)	1
Outcome feedback for		**10**
Object-oriented modeling	Alonso and Py (2009), Auxepaules and Py (2010), Auxepaules et al. (2008), Dranidis (2007), Dranidis et al. (2015), Soler et al. (2010a,b), and Virvou and Tourtoglou (2006)	8
Data modeling	Davis (2014) and Prados et al. (2006)	2
(iii) Learning analytics	Niere and Schulte (2005), Sedrakyan and Snoeck (2017), Sedrakyan et al. (2014a), Serral et al. (2016), and Tsarmpou and Tambouris (2015)	**5**
(iv) Gamification/Serious games		**6**
Gamification	Al-Tahat (2014) and Cosentino et al. (2017)	2
Serious games	Börstler (2010), Börstler and Schulte (2005), Boughzala et al. (2017), and Schulte and Niere (2002)	4

Table 2. Prevalent and emerging research themes in the review sample (multiple assignments allowed).

the conceptual model with the aim to support the acquisition of modeling knowledge for object-oriented modeling (Sedrakyan and Snoeck, 2013, 2015, 2017; Sedrakyan et al., 2014b) and for process modeling (Oppl and Hoppenbrouwers, 2017).

As second theme, *learning management systems* and *e-learning platforms* have been proposed to assist in learning and teaching conceptual modeling in 13 publications since 2006. Thereby, using learning management systems as, for example, Moodle is subject to 5 publications comprising approaches to support teaching object-oriented modeling (Brandsteidl et al., 2013, 2011; Tsarmpou and Tambouris, 2015), to support learning process modeling (Shabalina et al., 2015) and as part of a learning environment developed for teaching conceptual modeling (Daun et al., 2017). Examples for the use of an e-learning platform are the environment for business process modeling suggested in Neubauer (2012) and the virtual meeting tool applied to assist in learning object-oriented modeling skills suggested in Koivulahti-Ojala (2017) and Koivulahti-Ojala and Käkölä (2012, 2014). Applying a combination of an e-learning platform

and modeling tool support is suggested in 4 publications (Prados et al., 2006; Ramollari et al., 2011; Soler et al., 2010a,b): Modeling tools providing learning support are integrated into e-learning platforms offering further learning assistance, e.g., supporting communication, collaboration or continuous assessment.
Marked exceptions of publications suggesting tool support for learning and teaching conceptual modeling are an approach using visualization tools for teaching object-oriented modeling (Al-Tahat, 2014), publications proposing to use knowledge-based systems to support learning data modeling (Antony et al., 2005; Antony and Santhanam, 2007) and publications introducing a computerized environment integrating multi-media elements as basis for teaching enterprise modeling (Bider et al., 2015a,b).
Only 5 publications suggesting learning tool support comprise an explicit reflection on the underlying learning paradigm which in these cases is constructivist (Brinda, 2006; Eid, 2012; Fong et al., 2011; Snoeck et al., 2007) or combines a behaviorist and constructivist perspective on learning (Sedrakyan and Snoeck, 2017). However, there is a remarkable overlap between reviewed publications suggesting learning tool support and explicitly referring to a learning approach (11 publications), especially for the approaches of active learning (Hansen and Ratzer, 2002; Schulte and Niere, 2002) and collaborative learning (Baghaei and Mitrovic, 2005, 2006; Baghaei et al., 2007; de los Angeles Constantino-Gonzaléz and Suthers, 2000; de los Angeles Constantino-Gonzaléz et al., 2003; Gordon and Hall, 1998; Ramollari et al., 2011).
(ii) Feedback: Reviewing the final sample indicates continuous research effort on providing feedback to learners while learning conceptual modeling, i.e., 32 publications address this research theme. Broadly, the feedback approaches can be distinguished in *process-oriented feedback* which is provided immediately during completion of learning tasks and *outcome feedback* which is provided after a task has been completed (Sedrakyan and Snoeck, 2017, pp. 71f). A majority of publications in the final sample suggesting feedback, i.e., 22 publications including early publications from the 1990s (e.g., Gordon and Hall, 1998) and recent ones (e.g., Sedrakyan and Snoeck, 2017; Serral et al., 2016), can be categorized as proposing process-oriented feedback which is provided during modeling activities to learners—and which is considered more suitable to guide and support learning processes, especially in the context of self-regulated learning (e.g., Sedrakyan and Snoeck, 2017). Outcome feedback, suggested in 10 publications, is generally based on ex post evaluating models constructed by the learners against a reference model (e.g., Alonso and Py, 2009; Baghaei and Mitrovic, 2005)—involving the difficulty that there is no single correct solution but different adequate solutions for a modeling task (e.g., Daun et al., 2017). Besides very few exceptions in which an instructor provides direct feedback (e.g., Davis, 2014; Moreira and Ferreira, 2016), feedback is automatically provided within a software tool supporting the learning of conceptual modeling. It is remarkable that almost all suggestions for feedback in the reviewed sample are aimed at providing feedback at the syntactic and semantic level: Besides feedback regarding syntax errors, feedback, for example, on missing entity types or relationship types is provided when performing data modeling (e.g., Suraweera and Mitrovic, 2004). In addition, it becomes apparent that feedback in natural language is complemented with providing feedback, for example, by means of animated agents (e.g., Suraweera and Mitrovic, 2004) and supported by graphical visualizations—also denoted as augmented feedback (Sedrakyan et al., 2014b). Recently, based on learning process analytics, process-oriented feedback is provided in particular in the context of initiating self-regulated learning (Sedrakyan and Snoeck, 2013, 2015; Sedrakyan et al., 2014b). However, the other publications on feedback approaches in the review sample do not explicitly reflect on the underlying learning approach or paradigm. In addition, it is striking that we could not identify contributions in the final sample on providing feedback to learners while learning process modeling.
(iii) Learning analytics: In the ongoing educational and societal discussion on innovations in teaching and learning, learning analytics takes a prominent role. Learning analytics includes the collection, aggregation, analysis and evaluation of data on learners and their learning context, for example, with the aim to understand learning progress, to identify learning barriers and to reveal potential learning difficulties (e.g., Long and Siemens, 2011). Identified as an emerging research theme, 5 recent publications in the final sample discuss learning analytics, i.e., designing, developing and/or applying learning analytics (Niere and Schulte, 2005; Sedrakyan and Snoeck, 2017; Sedrakyan et al., 2014a; Serral et al., 2016; Tsarmpou

and Tambouris, 2015). Predominantly, approaches to learning analytics in the final sample are driven by collecting data during the execution of modeling tasks—as learning is supported by software tools and thus data on usage behavior can be collected in a straightforward manner, e.g., with data mining techniques (Sedrakyan et al., 2014a; Serral et al., 2016). The earliest approach to learning analytics in the final sample published in 2005 proposes empirical instruments for observing and collecting data on learners in a modeling tool, e.g., based on screen-videos complemented with generated and visualized log-files (Niere and Schulte, 2005). In addition, learning analytics is also used in a learning management system, i.e., Moodle, by collecting and analyzing detailed activity logs aimed at understanding and evaluating learning processes (Tsarmpou and Tambouris, 2015). The presented approaches are primarily based on logging events during the execution of modeling tasks, but do not consider logging further, more general tool interactions, e,g., mouse movements or using functionalities as syntax validation or requesting (automated) feedback. Only a few articles suggest logging learner-tool interactions with the aim to collect further relevant information, e.g., contextual information such as syntax or semantic verification and validation activities (Sedrakyan et al., 2014a; Serral et al., 2016). How to process tracking data in real-time to provide process-oriented feedback has been rarely discussed so far (e.g., Serral et al., 2016).

(iv) Gamification/Serious games: The fourth emerging research theme identified in the review sample pertains to the gamification of learning conceptual modeling. Generally speaking, the application of gamification, i.e., the selective application of game elements and game principles in non-game contexts (e.g., Deterding et al., 2011) as well as serious games, i.e., full-fledged games applied for non-entertainment purposes (e.g., Michael and Chen, 2006) aim to foster and accelerate learning and to increase learners' motivation and engagement. Six publications in the sample discuss gamifying the learning and teaching of conceptual modeling. Unsurprisingly, this research theme has emerged primarily in recent years with a first publication identified in 2002. The identified publications can be subdivided into those proposing the application of game elements, i.e., *gamification* (Al-Tahat, 2014; Cosentino et al., 2017) and those applying *serious games* (Börstler, 2010; Börstler and Schulte, 2005; Boughzala et al., 2017; Schulte and Niere, 2002). The recent approach proposed in Al-Tahat (2014) incorporates a three dimensional virtual environment as computer-supported game element in an instructional method for teaching object-oriented modeling. The other example for gamification is a generic model-based approach aimed at supporting the gamification of learning conceptual modeling which can be applied to learning scenarios (Cosentino et al., 2017). Regarding serious games, early approaches suggest role-playing games based on CRC-cards (Class, Responsibilities, Collaborators) for collaborative active learning of object-oriented modeling (Börstler, 2010; Börstler and Schulte, 2005; Schulte and Niere, 2002)—grounded in the learning approaches of active learning (Börstler, 2010; Schulte and Niere, 2002) respectively collaborative learning (e.g., Börstler and Schulte, 2005). Additionally, one recent approach proposes a serious game incorporating a three-dimensional environment for learning data modeling (Boughzala et al., 2017) in which users act as avatars. This approach is based on the teaching method of digital game-based learning (Prensky, 2001).

5 Discussion

Anchored in IS and Business Informatics curricula, teaching and likewise learning conceptual modeling has been a world-wide prevalent task for instructors and students of IS and related fields more or less since the inception of respective degree programs. Identifying "only" 121 publications in a systematic literature retrieval strikes as surprisingly low given the evident importance of this teaching and learning task and its accepted challenges. On the other hand, the publications in the review sample exhibit a remarkable breadth in terms of research themes from the obvious feedback to learning analytics to learner tool support. Another noteworthy observation is that less than half of the publications explicitly refer to learning approaches and/or teaching methods and only about one tenth of the publications entail explicit reflections on underlying assumptions about learning, e.g., with respect to learning paradigms. This is even more surprising as such reflections entail the opportunity to inform technical didactics and instructional design not least because of the many elaborate, often complementary perspectives on learning in the education sciences and, especially, in instructional design research (e.g., Smith and Ragan, 2005; van Merriënboer

and Kirschner, 2018). Education scientists have for long called for a greater attention to underlying assumptions about learning (e.g., Biggs, 1996)—as have IS researchers (e.g., Alavi and Leidner, 2001).
Reviewing the final sample regarding prevalent and emerging research themes leads us to identify four major themes in the current scientific discourse relevant for current and future research in this field:
(i) Regarding learning tool support, the review indicates that almost half of the reviewed publications suggest tool support for learning and teaching conceptual modeling with a focus on modeling tool support. Recently, these approaches are complemented by learning management systems and e-learning platforms supporting learners in this field. However, only few tool support approaches reflect on fundamental presuppositions, theories and learning approaches which in these few cases refer to a constructivist perspective on learning including the approaches of active and collaborative learning. This is surprising because a differentiated understanding of the intended learning processes and addressed learning difficulties provides guidance for designing modeling tool support or e-learning platforms (e.g., Alavi and Leidner, 2001). Hence, discussing the design of tool support for learners in the light of fundamental considerations on learning and their implications on learning support and assistance remains a promising research direction, e.g., through the lens of constructivist learning theories (e.g., Biggs, 1996). A first step could be to investigate learners' difficulties and barriers learners of conceptual modeling face in order to achieve a detailed understanding of learners' needs informing future design research on learning tool support.
(ii) Regarding feedback (to learners), the review finds a distinct focus on automated, process-oriented feedback—which, interestingly, can be traced back to suggestions in the 1990s (Gordon and Hall, 1998). Reviewing feedback approaches suggests that reflections on different kinds of feedback and, especially, interrelations with learning paradigms and learning approaches are scarce in the review sample. However, different perceptions of learning processes are assumed to translate into different kinds of feedback (e.g., Sedrakyan and Snoeck, 2017, p. 71) which are discussed regarding various purposes and regarding the timing of providing feedback—exhibiting considerable differences in terminology (Serral and Snoeck, 2016). Hence, exploring feedback for learning conceptual modeling in the light of learning paradigms, learning approaches and accompanying interpretations of learning processes constitutes a fruitful direction for future research. In addition, research on feedback solutions for learners of business process modeling opens a further path for future research to close the identified gap of missing contributions with this particular focus—especially given the relevance of business process modeling for IS research and practice (e.g., Davies et al., 2006; Recker et al., 2009).
(iii) With regard to learning analytics, it is observed that research in the review sample focuses on data mining techniques and other similar approaches for data collection. However, restricting data collection to logging modeling tool interactions constitutes a principle limitation of the presented approaches, and neglects other, presumably equally important aspects of the learning process, e.g., learner motivation and willingness-to-learn or the use of additional tools outside of the modeling tool, e.g., paper-based modeling. For example, asking learners to think out loud while working on a modeling task ("think aloud" verbal protocols, see Ericsson and Simon, 1980, 1993) promises further and more detailed insights into their reasoning (e.g., Haisjackl et al., 2016). Further reflection on assumptions about how learning occurs with respect to learning paradigms and learning approaches promises to provide guidance for exploring further techniques for collecting data as basis for learning analytics—constituting a fruitful avenue for future research studying learning and teaching conceptual modeling.
(iv) The gamification of learning conceptual modeling is identified as emerging research theme in the review sample—in line with increasing research interest in gamification and serious games in various disciplines (e.g., Deterding et al., 2011; Liu et al., 2013). Since virtual and augmented reality technology has even entered smartphones and tablets, it is evident to link these technologies to innovative teaching and learning strategies for conceptual modeling. Moreover, the review finds only very few contributions to this research theme so far (e.g., Al-Tahat, 2014) which opens a path for innovative, original contributions. Moreover, in the light of the recent emphasis on active and collaborative learning, the gamification of learning and teaching conceptual modeling adds a new angle which is assumed to increase learners' motivation and engagement. However, further research is needed to evaluate such (hypo-)theses and, hence, constitutes another path for future research on learning and teaching conceptual modeling.

6 Conclusion

Analyzing prior work on learning conceptual modeling leads us to identify (i) learning tool support, (ii) feedback, (iii) learning analytics and (iv) gamification/serious games as prevalent and emerging research themes in the scientific discourse in this field. Reflections on underlying learning paradigms, learning theories, teaching methods or, more generally, assumptions about learning have surfaced surprisingly rarely in the analyzed literature. Hence, the present findings encourage further discussion on framing the learning of conceptual modeling in the light of learning paradigms and let us outline four major suggestions for future research which provide the opportunity to tie in with a large body of literature in education sciences and instructional design research: (1) Design research on tool support for learning and teaching conceptual modeling informed by fundamental considerations on learning processes and their implications on learning support and assistance in line with learners' needs; (2) Exploring approaches for providing (automated) feedback to learners of conceptual modeling in the light of different perceptions of learning processes; (3) Considering further data collection approaches as basis for learning analytics for conceptual modeling beyond learner-tool interactions, e.g., verbal protocols or further contextual information; (4) Design research on applying virtual and augmented reality technology for gamifying the learning of conceptual modeling in the light of active and collaborative learning approaches, accompanied by evaluating the impact of the technology use on learning processes. Overall, the present findings strongly suggest that the current discussion will benefit substantially from further contributions taking complementary angles and methodological stances on learning conceptual modeling involving theoretical, empirical and design science research to jointly advance our knowledge on learning (and teaching) conceptual modeling. Research efforts following the suggested directions are expected to also benefit practitioners in teaching conceptual modeling by providing new instructional designs and methods building upon tool support informed by reflections on learning paradigms and learning approaches.

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